12 September 2002

Naval Facilities Engineering Command
Ergonomic Risk Assessment for
Navy Public Works Center

INTRODUCTION

This report summarizes the ergonomic risk assessment conducted for the Public Works Center (PWC) during the week of October 15, 2001. This assessment is based upon interviews with workers, an Industrial Hygienist, Safety Specialists, and an evaluation by a Naval Facilities Engineering Command (NAVFACENGCOM) Ergonomist.

The trade operations reviewed present opportunities to reduce the risk of work-related musculoskeletal disorders and improve safety, occupational health and productivity. Musculoskeletal Disorders (MSDs) are injuries and illnesses that affect muscles, nerves, tendons, ligaments, joints, spinal discs, skin, subcutaneous tissues, blood vessels, and bones. Work-related Musculoskeletal Disorders (WMSDs) are:

- Musculoskeletal disorders to which the work environment and the performance of work contribute significantly or
- Musculoskeletal disorders that are aggravated or prolonged by work conditions.

Recommendations to the command to reduce the probability of injury include new equipment[1] and implementation of administrative controls[2]. Recommendations are included with as much vendor information as possible to assist in the evaluation of products and services. Input gathered from the workers, safety specialists, and other personnel to evaluate equipment before purchasing is recommended. This process will increase product acceptance, test product usability and durability, and take advantage of employee experience.

BACKGROUND

Injury Data: In fiscal hear 2000, Sprains and Strains accounted for 52% of the mishaps for workers at the activity. The greatest number of sprains and strains by trade can be attributed to electricians, Heating Ventilation and Air Conditioner (HVAC) workers, and pipe-fitters.

Process: Electricians, HVAC workers, and pipe-fitters respond to maintenance requests and work at the site of the problem. Work requests and associated processes vary greatly by task, trade, and location. Changes to the work location are not feasible since the employees are responsible for a variety of sites in the area. The types of tasks are physically demanding and involve ergonomic risk factors, which can cause or contribute to WMSDs. The vehicles and personal tools for the tradesmen act as mobile work sites or tool rooms.

ERGONOMIC STRESSORS

Tradesmen are regularly exposed to ergonomic risk factors including awkward postures, excessive force, contact stress, and vibration. When risk factors are combined with frequent exposure (repetition) and extended duration they can lead to WMSDs. The tradesmen's duties are often physically demanding, resulting in inadequate rest and recovery, which leads to fatigue and discomfort.

For example: HVAC workers and electricians frequently work for long periods with their hands held over their head to repair ventilation systems. Pipe-fitters commonly hold or sustain postures while joining pipes and handle heavy tools and materials. Examples of specific ergonomic stressors include:

Awkward Postures: Tradesmen are commonly forced into awkward postures to maintain items in hard to reach areas and confined spaces. Tradesmen may be required to work in crawl spaces on their knees, on ceilings with their hands held above their head, and even below ground level while lying on their backs. When awkward postures are sustained for any period, static loading of the muscles occurs which may lead to muscle fatigue and soreness. Holding the body in an awkward posture such as kneeling, holding a tool above the shoulder, or bending over an object, can lead to rapid muscle strain and fatigue. Figure 1 shows a pipe fitter in an awkward posture with his weight resting on his toes and knees, and with his neck, and back bent. The muscles must apply considerably more contraction force to sustain this awkward posture, particularly if the position is maintained for any duration. Sustaining an awkward posture can impede blood circulation, nerve conduction, and cause muscle fatigue. Repetitive awkward postures, such as wire stripping, sanding, and ratcheting can contribute to WMSDs.

Figure 1: Pipe-fitter in awkward posture

Force: Excessive force such as using the hand as a hammer or a sustained force such as holding the trigger of a pneumatic tool can strain muscles and joints. Forceful exertions can place high loads on the muscles, tendons, ligaments, and joints being used. Forceful exertions also include lifting heavy objects such as water conduits or other large pipes. Increasing the force required to lift a load also means increasing body demands (i.e., greater muscle exertion is necessary to sustain an increased effort) and imposing greater compressive forces on the spine. As force increases, muscles fatigue more quickly. Figure 2 shows electrician's supplies, which were carried in by hand on multiple trips to the job location. Prolonged or recurrent exertions of this type can lead to WMSDs when there is not adequate time for rest or recovery.

Figure 2: Electrician's Supplies

Repetitive Motions: Many of the maintenance tasks performed by the tradesmen such as painting, cutting, welding, fastening and riveting are repetitive in nature. Motions that are repeated frequently with little variation may cause fatigue and overuse of the muscles, tendons, and joints that are involved in the exertion. Overuse leads to muscle strain, inflammation of joints and tendons, and increased pressure on nerves. As exposure continues or intensifies (e.g., pace increases) tears in muscle fibers occur. As duration and frequency of repetitive motions increase, so does the risk of injury due to overuse and lack of adequate recovery time. The tradesmen tend to perform repetitive hand motions in awkward postures, such as when stripping wires. Performing repetitive motions in awkward postures (e.g., bent wrists, extended arms) adds significantly to the muscular effort required to perform each motion. The added force hastens the onset of fatigue and increases the likelihood of injury from overuse. The joints are most susceptible to repetitive motion injuries, especially the wrists, fingers, shoulders, and elbows.

Vibration: Tradesmen often use vibrating tools such as sanders and pneumatics. Prolonged exposure to hand-arm vibration may cause peripheral neuropathy (disease of the nervous system) with symptoms such as numbness and pain in the hands and muscle weakness. Hand-arm vibration syndrome (HAVS) and carpal tunnel syndrome (CTS) occur after the long-term operation of many kinds of vibrating tools.

Contact Stress: Contact stress occurs between a hard surface such as a tool or the edge of a table and soft tissue of the body. A hard object like a tool handle can exert concentrated force on small areas of the body, like the hand, which reduces blood flow and inhibits nerve function. Prolonged contact stress can lead to permanent injury of nerves and tendons. The hand is particularly susceptible to damage from contact stress because there are a large number of nerves throughout the hand and fingers and a number of blood vessels run through the palm where hand tools normally press. Additionally workers tend to carry tools in a bucket, as shown in figure 3. When a bucket is weighed down with tools, the handle can cause mechanical stress to the hand. The tongue and groove pliers, also shown in figure 3, are an example of a worn tool with a narrow handle, which can cause mechanical stress to the tissue in the palm. Biomechanical stress can also be created in the knees when a worker kneels or squats to perform a task.

Contributing Factors: Due to the nature of their work, tradesmen are frequently exposed to environmental conditions, such as cold and wet weather, which are considered contributing factors to the development of a WMSD. Exposed metal tool handles can become quite cold. Cold environments or focused cold temperatures can reduce the dexterity and sensitivity of the hand. Cold temperatures, for example, may cause the worker to apply more grip force to hold hand tools and objects. Also, prolonged contact with cold surfaces can impair dexterity and induce numbness. Cold is a problem when it is present with other risk factors and is especially problematic when it is present with vibration exposure

PWC also has an aging workforce. Age is a risk factor for WMSDs and many of the current injuries were experienced by older workers.

Figure 3: Pipe-fitter's tools

General Recommendations

Ergonomic Team: PWC has an established and trained a worker-based ergonomic team. A worker-based team is a recommended method to reduce risk and improve occupational safety and health in the workplace. Worker-based teams draw upon the knowledge and experience of the workers and acknowledge the vital contribution they make to any Occupational Health and Safety Program. The ergonomic team should identify jobs with ergonomic stressors and suggest solutions before problems begin; as well as evaluate jobs identified as potential ergonomic problem areas by supervisors and employees. PWC San Diego has a very successful ergonomic team. The program manager has offered to provide any possible assistance and advice. Please contact T Gogue at (619) 556-1551 GogueTS@PWCSD.NAVY.MIL

Members of the ergonomic team should be encouraged to act as the contact person for their work area by increasing awareness about ergonomics and encouraging workers to report early WMSD symptoms or concerns regarding non-ergonomic work environments. The Safety Office could provide team members with ergonomic-related educational materials to present at monthly safety meetings in their work areas. The ergonomic team and safety office should always document success stories and lessons learned to share with others. Other suggestions for promoting ergonomic awareness include annually rewarding the best ergonomic improvement developed and implemented by the ErgoTeam, and incorporating employee suggestions for reducing ergonomic risk in the workplace into the employee suggestion program.

Training: In order for employees to be aware of ergonomic stressors and methods to reduce risk, they should receive basic training. Employee basic ergonomics training should educate employees on the meaning of ergonomics and how to recognize ergonomic risk factors in their work place and who to report them to. Employees should also be aware of signs and symptoms of WMSDs in order to encourage early reporting. Employees should also be trained in proper lifting techniques and work postures. Recommendations for training topics can be found in OPNAVINST 5100.23F chapter 23 Ergonomic Program.

Administrative Controls

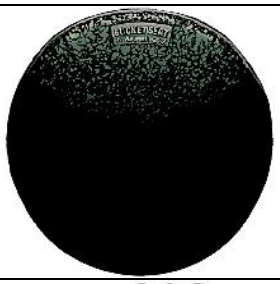
Ergonomic stressors in the workplace can be abated through two types of controls. Administrative controls are a means of reducing exposure to ergonomic stressors through changes in work methods, such as stretching, two-person lifting, work breaks, and job rotation. By varying job tasks employees should utilize different muscle groups and increase the worker's stress tolerance. Engineering controls seek to eliminate ergonomic stressors in the work place by designing out the hazard. Engineering controls are the preferred means of abatement but administrative controls are accepted when engineering controls are not feasible. Department of Defense Instruction 6055.1 declares engineering controls the preferred ergonomic abatement method.

Stretching: Employees can reduce discomfort and risk of injury by regularly exercising and stretching throughout the workday. Stretching relieves tension, promotes blood flow and decreases muscle fatigue. Engineering controls are not always feasible in typical tradesmen operations because the tasks are performed at various locations which are not conducive to task redesign. Stretching can help employees avoid injury. Employees should be encouraged to participate in a Stretch and Flex program such as ErgoJoe. The ErgoJoe program was implemented at Puget Sound Naval Shipyard in 1997. A Safety Specialist served as a mentor and coordinator of the program, visiting work areas and educating employees. The program resulted in a 20% shipyard-wide reduction in back injuries.A Work-break schedule based upon physical exertion can also break up a task and reduce overall physical stress.

Vibration Measurement: In order to reduce the risk of Hand-Arm Vibration Syndrome (HAVS) to the worker, the Industrial Hygienist should regularly measure vibration levels on power tools. Tools with vibration levels in excess of the Threshold-Limit Value according to the 2001 American Conference of Governmental Industrial Hygiene guidelines should be clearly marked with a maximum duration of acceptable exposure. For example, tools with vibration levels above 12 m/s^2 should be used no longer than an hour a day. If vibration measurements are not obtainable, a Swedish database contains some basic parameters for wide range of powered hand tools http://www.niwl.se/hitta/default_en.asp

ENGINEERING CONTROLS

Tool Use: While it is a good idea to select specific tools for the task to avoid carrying more tools than necessary. if a bucket is used to carry tools, it can be turned over and used as a seat while working to relieve some of the pressure created by kneeling or stooping.

Tool Aides			
Duluth Trading www.duluthtrading.com 1-800-505-8888	Bucket Seat Item 90010	$6	
	Bucket Boss	$14-$30 depending on number of pockets	
	Bucket Strap (not to be used with Bucket Boss) 66212	$15	
	Bucket Grip Item 8010	$4	

	Tool Bag 81526 Tool bags available in a variety of shapes and sizes	$40	

Kneepads and wedges can be used to alleviate stress to the knees while kneeling or squatting.

Kneeling Aides			
Alimed www.alimed.com 1-800-225-2610	Knee pad JA70039 JA70041	$19- $23/pair	
	Knee Saver JA62161	$40/pair	

Tool Storage: An example of a pipe fitter's truck is shown in figure 4. Parts are stacked on the floor and on shelves in boxes, creating an inefficient use of space. Due to the lack of organization, searching for a tool or part can be a time consuming task. Tools are often carried in cardboard boxes, which are difficult to carry since they lack handles. Cardboard boxes can also fail and fall apart with repeated use, which can possibly cause a foot or leg injury from falling tools.

Figure 4: Pipe-fitter's Truck

A larger truck with a workbench would allow the employees to accomplish more work in the truck rather than onsite. Depending on the trade, a mule hoist for lifting, ladder loader for the ladder and/or a pull out vice for cutting may allow more tasks to be completed in the truck. These improvements have been successfully implemented at PWC San Diego. This should increase productivity and decrease the number of tools carried to the job site.

Truck Accessories			
Team TEMCO 800-322-7997	EZ Ladder Loader	$1,008	
Porta-Hoist 1-877-573-3004	Porta-Hoist 500	$670	
RS-Q Hoist 1-800-265-0182	Mule Hoist		

The walls of the truck should be equipped with additional shelving or a tool peg board to increase the storage utilization of the truck. The cardboard boxes should be replaced with totes, which have better handles for lifting and will not breakdown.

Truck Organizers			
C&H 1-800-336-1331 www.chdist.com	Allibert Stack and Nest Containers Totes with hand holds Schaefer Polyethylene Industrial Containers Akro-Mils Straight Wall Containers	$11-$23 $9-$32 $8-$15 depending on size	

Each truck should be outfitted with a dolly to carry tools and supplies. The dolly can lock to the outside of the truck or fold up to store inside the truck. A stair-climbing dolly is recommended. Diagrams depicting proper work postures and practices could also be posted on truck walls.

Stair Climber			
Castle Forklifts 44-0-1788-560531 www.stairclimber.co.uk	Stair Climbing Sack Truck	$125 + international shipping	

Tool Selection: Although the tradesmen are responsible for providing their own tools, additional training will help with future tool selection. Additional ergonomic tools could be made available for checkout from the tool room. Rechargeable tools and torque multipliers are ways to reduce the stress associated with repetitive tool use. In order to encourage employees to invest in ergonomic tools, secure locking storage should be made available to all tradesmen.

Postures: When working with handtools it is important to select the proper tool for the task. Tools should be kept about elbow height. When working on a vertical surface a tool a pistol grip is preferred, as shown in figure 5, to maintain a neutral wrist posture. When working on a horizontal surface an inline tool, as shown in figure 6, is preferred. An inline tool utilizes a power grip, as shown in figure 7.

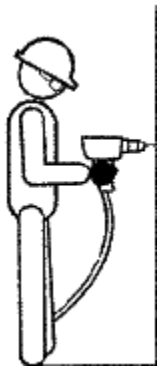


Figure 5: Pistol grip

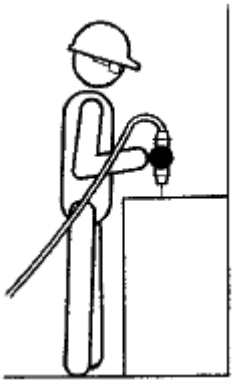


Figure 6: Inline tool

Figure 7: Power Grip

Handle Thickness: When selecting tools it is important to consider the thickness and length of the tool. The thickness of the tool handle depends on the type of handgrip and the operator. Handles, which are too thick, require greater force to hold on to and operate. The handle should be long enough to gain a mechanical advantage when using the tool, but not long enough to press into the palm of the hand.

Power grip: Handles that use a power grip are preferred. A power grip is when the entire hand is used and the thumb overlaps or touches the forefinger such as with a hammer, refer to figure 7. For power grip tools, a handle diameter between 1” and 1.5” is preferred to accommodate a population including females. For power screwdrivers, a diameter of about 2” is optimal. Straight handled tools, such as a hammer, with an oval-shaped handle should have a grip that is 1.25” by 1.75”. The tool should be long enough for all fingers to come in contact with the tool. Tool length should be at least 4”, 5” if gloves are used.

Precision grip: A precision grip is when you use a pencil or a knife, as shown in figures 7 and 8. When using a precision grip a diameter of .3” to .6” is recommended. For an external precision grip a tool length of about 4” is preferred in order to allow the first finger and thumb to provide support. For an internal precision grip, the handle should extend past the palm but not touch the wrist.

Figure 8: Internal Precision Grip

Figure 9: External Precision Grip

T-shaped handles: For tools with a "T" shaped handle, figure 10, a handle diameter of about 1" is recommended.

Figure 10: Nut Spinner with T-handle

Two-handles: When using tools with two handles, like the pliers shown in figure 11, the span between the handles should be less than 3.5" to accommodate a larger male population, and 3" maximum to accommodate a smaller population that includes females. Longer handles are recommended if the user is wearing gloves or exerting a forceful power grip. In order to reduce the force and repetitive awkward motion required to spread the handles back open, a spring loaded handle is recommended. A stop point or spreader bar between the handles will also eliminate pinch points. The tool handles should be no longer than 4.5" long.

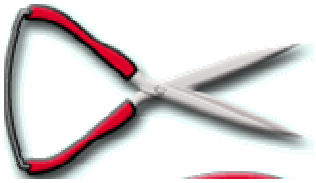


Figure 11: Tool with two handles

Power tools: Tools with low vibration or vibration-dampening mechanisms will reduce the risk of developing vibration-related WMSDs. Padded handles and balanced tools are examples of methods to reduce vibration. An Industrial Hygienist should set exposure limits for vibrating tools. It is important to note that a manufacture claim to 'reduce vibration' may mean a lower motor speed, which could require longer tool use resulting in the same vibration exposure. Finger triggers should be at least 1.5" wide and operated by 2 or 3 fingers. The force required to activate the trigger should be less than 4lbs. Thumb operated triggers are not recommended for repetitive operations.

Handle Shape: When selecting tools it is important to avoid tools with hard, sharp edges or abrupt curves, which may cause contact stress. Handles with grooves or channels for fingers are not recommended. Grooves can create a compressive force on the hands, spread the fingers apart, and keep the hand in a fixed position. Circular or oval

shaped handles are recommended. A tool handle should be made of a compressible material to absorb energy and vibration, such as rubber or a compressible plastic. The handle should have a high coefficient of friction to keep it from slipping out of the hand. The surface of the tool should not be capable of absorbing fluids or contaminants. The handle should be non-conductive to protect the worker from extreme temperature. Tools with bent handles promote neutral wrist postures as shown in figures 12 and 13.

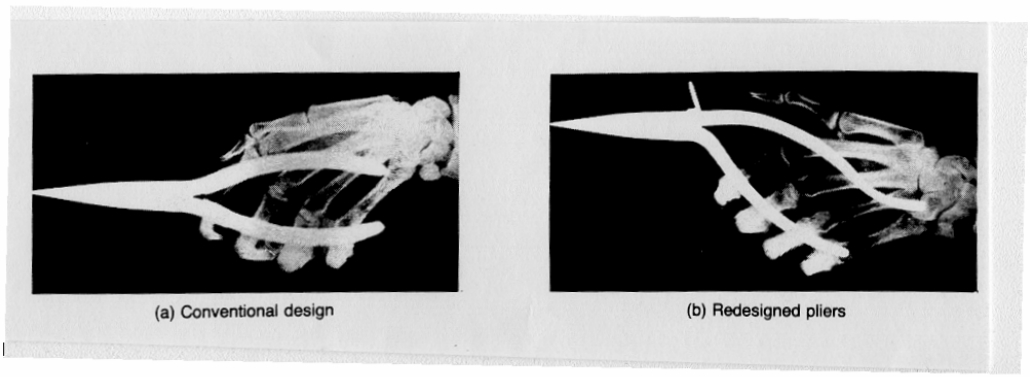


Figure 12: Traditional and ergonomic pliers

Figure 13: Traditional and ergonomic hammers

User-FriendlyTools			
Alimed www.alimed.com 1-800-437-2966	Ergonomic hammers	$37-$50	
	Spring operated wire cutters	$30	

	Ergonomic needle nose pliers	$30	
	Spring operated combination pliers	$27-$28	
	Anti-vibration Gloves	$38-$50	

Additional Resources

Additional resources in ergonomics are available on the Naval Facilities Engineering Commands Safety web site under the Ergonomics tab:

http://www.navfac.navy.mil/safety/

The site is currently under construction, if the requested materials are not on the website, please contact the Navy Ergonomics Program.

Employee Ergonomic Awareness training.
Ergonomic Awareness: Vibration.
Tools: Design and Selection
ErgoJoe stretching exercises.
Tool purchasing guide- including specific tools recommended to the Navy
Lessons Learned and Success Stories from PWC San Diego

Naval Shipyard Puget Sound uses the following two references in their tool selection process:

An Ergonomics Guide to Hand Tools, publication #203-ER-95 published by the American Industrial Hygiene Association
A Strategy for Industrial Power Hand Tool Ergonomic Research - Design, Selection, Installation, and Use in Automotive Manufacturing, publication #95-114, published by NIOSH

Additional resources can also be found on the internet. All internet links are current as of January 2002.

Examples of employee training for tool use can be found at-
http://www.cdc.gov/niosh/elcosh/docs/d0200/d000260/d000260.pdf
http://gala.ccohs.ca/oshanswers/safety_haz/power_tools/
http://www.mrotoday.com/mro/archives/exclusives/GenuineErgonomic.htm

Tools for assessing ergonomic risk:
Washington State-including check lists-
http://www.lni.wa.gov/wisha/ergo/eval_tools/default.htm
Job Requirements and Physical Demands Survey-
https://www.afms.mil/ergo/dl_jrpd.htm
Air Force Program Management Guidelines and Level I assessment guides for Administrative, Warehouse and Service, and Maintenance and Inspection Areas-
https://www.afms.mil/ergo/pubs.htm

*Some information has been removed from this report that is specific to the activity.

[1] Equipment purchase without proper and repeated training will not mitigate risk and may in fact increase hazards. This report does not constitute an endorsement of any particular product. Rather, it is a recitation of how Navy personnel have addressed a particular work place safety issue. Neither the Navy nor its employees and agents, warrant any product described in this report for any use, either general or particular.

[2] Administrative controls are management-controlled work practices and policies designed to reduce exposures to work-related musculoskeletal disorders (WMSDs) hazards by changing the way work is assigned or scheduled. Administrative controls reduce the exposure to ergonomic stressors and thus reduce the cumulative dose to any one worker. Examples of administrative controls that are used in the ergonomics context are employee rotation, employer-authorized changes in the pace of work and team lifting.