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Case Studies

An Ergonomic Evaluation of Trail Workers at Yosemite National Park

Dawn Tharr, Column Editor

Reported by Daniel Habes and Mark Schiefer, M.D.

On May 9, 1997, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from the U.S. Department of the Interior. The request specified cases of musculoskeletal disorders of the upper and lower extremities and back among workers who build and maintain the back country trails of Yosemite National Park. Some of the work tasks specified as particularly hazardous were "drilling," "hammering," "shaping granite rocks," "lifting rocks and timbers," and "backpacking on rough terrain with heavy loads."

During August 25–28, 1997, NIOSH visited the Buena Vista Lakes camp of Yosemite National Park, a site selected by the management of the Park's trail maintenance department. The visit included an opening conference, an evaluation of the trail maintenance projects being performed at the time, interviews with each of the workers, videotape and still photos of the various work tasks, and measurement of manual forces required to perform some of the work tasks.

Background

The 840 miles of hiking trails at Yosemite National Park are built and maintained by the trail crew members of the Park's Maintenance Division. Generally, there are four or five crews of about 20 workers each assigned to these duties, but due to the damage from floods in January 1997, the number of trail maintenance crews was increased to 10, representing 127 workers. The Maintenance Division employs about 400 of the Park's 750 peak season workers. Trail crew members are primarily seasonal workers employed by the National Park Service (NPS) or members of the California Conservation Corps (CCC). Other sources of seasonal personnel are the Student Conservation Association, Animal Packers, and locals from the Central Valley Opportunity Center. CCC workers who maintain the back country trails are part of the AmeriCorps program. Only the injuries and illnesses sustained by NPS employees are contained in the Park's worker's compensation records. Many of the NPS workers are former CCC workers. At the time of the NIOSH visit, the Buena Vista Lakes crew was comprised of 5 NPS workers and 14 CCC workers.

Yosemite leads the National Park system in compensation costs due to injuries sustained by its workers. In 1996, the total cost for worker's compensation was about $700,000.

In anticipation of greater participation in the costs of injured workers, Yosemite National Park has begun to develop a loss control program. It is envisioned that the program will contain elements of improved worker training, greater emphasis on safe work practices, and a change in the culture of maintaining and building the maximum number of hiking trails allowed by the budget, without regard for injuries and compensation costs. A key component of this effort has been the creation of a liaison position between the worker's compensation office in Personnel, the Safety Office, and the Maintenance Department. The duties of this position are to establish a communication link among these three offices for purposes of controlling losses due to injuries and illnesses while ensuring that the hiking trails are maintained according to Park standards of quality and safety. Another emphasis area of this position is the identification of suitable light-duty jobs for injured trail crew members so that time away from the job can be minimized or avoided.

The Department of the Interior requested an HHE to complement the loss control efforts at Yosemite with an ergonomic evaluation of the physical demands of trail work. Because efforts were underway to reduce the compensation costs sustained by the Park, officials thought it would be an appropriate time to also review work and safety procedures for purposes of improving worker health and reducing the risk and/or severity of injury. The specific question posed to NIOSH in this HHE request was whether there were alternate work methods, tools, or safety equipment that could be implemented or used by the trail crew management to reduce the likelihood of injury or illness to workers performing the various tasks of maintaining and building hiking trails in the park.

Methods

Ergonomic

The ergonomic evaluation methodology consisted of an assessment of the various work tasks observed at the hiking trail projects taking place at the Buena Vista Lakes camp site. The types of postures, movements, and work activities that were assessed are discussed later in the Evaluation Criteria Section. Attention was focused on the manner in which the work was done and the tools that were used to perform the various tasks. To aid in the evaluation, videotapes and still photos were taken of workers and

tools, and each trail crew member was interviewed. The manual force requirement of moving a rock with a lever bar and the weight of some items used at the camp site were measured with a digital force meter. The following is a brief description of the job tasks observed during the ergonomics evaluation.

Job Descriptions. At the beginning of the season, trail crew efforts are concentrated in the "front" country (valley) part of the park where trails are cleared of debris, raked and shoveled, and trees are cut and trimmed. None of these activities was observed during the NIOSH evaluation. At the time of the NIOSH visit, the trail crews were in the construction phase of their seasonal activities, which includes reconstructing trails and bridges in the "back" or "high" country.

Buena Vista Lakes is located at an elevation of 9100 feet in the south end of the park, approximately 11 miles from the nearest trail head. Daytime high temperatures were in the 70s˚F and overnight lows were in the mid-40s˚F. The terrain is mountainous and covered with granite rocks. These rocks, some weighing hundreds of pounds (lbs), are used to make the steps and walkways of the hiking trails.

Trail Projects. Each of the trail crew members is assigned, with one or more co-workers, to a project located in the general vicinity of the main camp site. After breakfast, the crew spends about 15–20 minutes stretching and performing a variety of leg, arm, shoulder, and wrist exercises before hiking to their assigned project. Everything needed for the project must be carried to the site, including a lunch and enough water to last a workday. Tools such as rock or lever bars, hammers, sledge hammers, shovels, and picks are carried once to the work site and left there each evening until the project is finished. The work shift began at 7:00 a.m. and ended at 4:30 p.m. The shift schedule was designed so that over a two-week period, eight 9-hour days were worked, followed by an 8-hour day, and then a day off. The NPS workers were allowed to hike back to the trail head on days off and on weekends, whereas the CCC workers had to remain in the back country for the entire season (mid-April to mid-September).

At the time of the NIOSH evaluation, all of the trail crew members were involved in "rock work" projects. These projects primarily involve the construction of granite steps that form the trails in the high country. These steps are made from the various-size granite rocks found on the mountainsides. After a project is planned, the workers select the proper size rocks from those in the area of the project. If the selected rock is some distance from the trail, it must be moved to the site. The rocks are dislodged with rock bars and rolled in a controlled manner to the desired location. In instances where the rock bar is judged to be inconvenient or unsafe, the workers move the rocks by hand using team pushing and lifting approaches. Either at the trail site or any place along the way, the workers may choose to shape or split the rocks. Shaping, which is pounding on the rock to remove material, is done with various hand-held hammers and sledge hammers. The most commonly used are 3- and 4-lb hammers and two-handed (double-jack) sledge hammers ranging from 8 to 16 lbs. The 12-lb sledge hammers are used about 80 percent of the time. Splitting rocks is accomplished by drilling two or more holes in the rock with a gas-operated drill called the Pionjar™. This tool weighs 75 lbs and has to be carried by hand to the work site. After the holes are drilled, "plugs and feathers" are pounded into the holes with an 8-lb double-jack (sledge) hammer until the rock splits.

Other tools used to construct rubble stone masonry steps and walls include shovels for digging a "footing" (the hole where the "key stone" or first rock is placed). This rock acts as the key strong point for the rest of the stones placed above and against it. Shovels are also used to extract stones from various locations near the work site. Once the stones are dug out, they are maneuvered to the work site either by hand or with a rock bar. Picks and dual-purpose pick/axe tools called "pulaskis" are used as needed to break up hard dirt by swinging the tool into the ground and loosening the soil prior to digging out the footing with a shovel.

Two types of step-making techniques are used on the trails, depending on the needs of the project. "Terracing" is a method where large, somewhat irregular rocks are used to form the steps. Spaces between successive steps are filled with crushed stone, called "crushing fill." "Riprap" is a technique where smaller rocks that are more finely shaped with sledge hammers and single jacks are adjoined like a puzzle to form the treads and risers of the steps. Stones set side-by-side are in direct contact with each other (gaps between 1/2 and 5 inches). These gaps are "stuffed" and "chinked" with finely crushed and small stones to achieve a snug, weather-resistant fit. Tools used for stuffing and chinking can be the plug from a plug and feather set, the end of a hammer or a rock bar, or a sturdy stick. "Chinking" is a multipurpose term that can also describe the leveling of adjacent rocks by placing small piles of crushed fill beneath them ("chinking up a rock"), or the placing of small rocks under a rock that is being moved to prevent it from rolling back to its initial position.

Gloves, standard hiking boots, hard hats, safety glasses, ear plugs, dust masks, and half-face cartridge respirators are supplied to the workers for performing the above job tasks. Hard hat, gloves, and glasses are the safety wear used for most projects. The dust mask is worn when breaking rock, and the respirator and ear plugs are worn when drilling into rock with the Pionjar™.

Kitchen Patrol (KP). Each day, one of the CCC trail crew members stays at the camp site with the cook to perform KP duties. (The cook on a crew comprised of only NPS workers gets no help during the workday.) These include helping the cook prepare food for the day, washing dishes and towels, cutting firewood/tending the fire, unloading the supply mules, attending to the latrines, and carrying water from the spigot to the 30-gallon cans located on the camp fire (about 40 paces). In the morning and

TABLE I
Yosemite National Park employment and injury totals for the years 1995–1997

Year	Total park service employees	Total park service injuries	Total injuries due to overexertion	Trail employees		Total injuries trail (NPS only)	Total injuries due to overexertion (NPS only)
				Total	NPS		
1995	672	180	87	70	44	26	17
1996	650	176	60	84	54	35	30
1997	750	248	87	127	81	26	19
		tot = 604	tot = 234			tot = 87	tot = 66

evening, when all the crew members are at the camp site, the chores of carrying water (both from the water tap to the fire and from the fire to the cleaning table) and cleaning up after dinner are shared by all. The fire was located about 40 or 50 paces from the wash table. Water used for cooking and leaning was disposed of by dumping it into a slow-draining pit located behind the wash table.

Employee Interviews

Each of the trail crew members, including the supervisors and the cook, was interviewed. There was no formatted questionnaire administered, but specific information was obtained from each worker. The particular items were:

- Age, gender;
- Occupational history (NPS or CCC and how many years of each);
- Physical fitness prior to working at Yosemite;
- Any history of musculoskeletal problems before joining trail crew;
- Description of the trail maintenance tasks worker had performed;
- Rating of which tasks were the most difficult and why;
- What aspects of the job could be changed or improved, such as work organization, training, tools used, safety equipment, etc.;
- Any current aches, pains, or injuries and, if so, the part of the body affected;
- Work task being performed when the ache, pain, or injury occurred; and
- Whether the pain affects current work.

Medical. Injury statistics, compiled by the Personnel Office, were reviewed for the years 1995–1997. The data are summarized in Table I.

Evaluation Criteria. Overexertion injuries, such as low back pain, tendinitis, and carpal tunnel syndrome, are often associated with job tasks that include: (1) repetitive, stereotyped movement about the joints; (2) forceful manual exertions; (3) lifting; (4) awkward work postures; (5) direct pressure on nerves and soft tissues; (6) work in cold environments; or (7) exposure to whole-body or segmental vibration.[1-3] The risk of injury appears to be increased as the intensity and duration of exposures to these factors are increased and the duration of recovery time is reduced.[4] Although personal factors (e.g., age, gender, weight, fitness) can affect an individual's susceptibility to overexertion injuries/disorders, studies conducted in high-risk industries show that the risk associated with personal factors is small when compared to that associated with occupational exposures.[5]

In all cases, the preferred method for controlling/preventing work-related musculoskeletal disorders (MSDs) is to design jobs, work stations, tools, and other equipment items to match the physiological, anatomical, and psychological characteristics and capabilities of the worker. Under these conditions, exposures to task factors considered potentially hazardous will be reduced or eliminated to the extent feasible.

Results

Ergonomic Risk Factors

Trail Projects. Seven trail construction projects were in progress at the time of the NIOSH evaluation. Approximately 60 minutes of video were taken of the various activities performed by the workers. A breakdown of the time spent in these activities is shown in Table II.

Work activities during the evaluation were not sampled in any systematic manner, but all major work tasks were recorded. The NIOSH investigators hiked to the various job sites and observed whatever was going on at the time the site was visited. NO distinction was made between single and multiple workers performing an activity. That

TABLE II
Activity analysis of trail workers

Activity	Time spent (min.)
Moving rocks by hand	10.2 (17%)
Moving rocks with a lever bar	11.8 (19.7%)
Using hammers	11.1 (18.5%)
Carrying rocks	4.3 (7.2%)
Stuffing/chinking	4.3 (7.2%)
Drilling rock	2.3 (3.8%)
Digging with shovels	.7 (1.1%)
Other: evaluating work strategies, selecting and carrying tools, measuring rocks, etc.	15.3 (25.5%)

is, if three people were attempting to move a rock for one minute, one minute was added to the total amount of time recorded for that activity. In general, the heavy tasks such as moving rock, either by hand or with a rock bar, were performed by more than one worker, whereas the other tasks, such as hammering, drilling, and digging, occupied one worker while the other workers looked on and/or prepared themselves for the next work task.

Hand-intensive activities requiring repetitive motions and application of muscular force comprised 74.5 percent of the videotape recorded. Moving and carrying rocks took place nearly 44 percent of this time. About a quarter (25.5 percent) of the workers' time was spent in light or non-physical activities such as selecting tools, maneuvering themselves and preparing for subsequent tasks, and measuring rocks and spaces on the trail for placement of steps.

Many awkward postures involving the trunk and extremities, and activities that impart physical stress to the body, were part of the activities comprising the rock work jobs. Moving rocks by hand required squatting, bending at the waist (trunk flexion), and lifting and pushing with extended wrists. Rock bar work required stooping, pushing, and pulling; breaking and shaping rock required shoulder extension, flexion, and rotation, and trunk flexion and squatting. Crushing rock and stuffing cracks required squatting and shoulder movements, and drilling rock required lifting, carrying, pulling, pushing, and trunk flexion. Finally, working with a shovel required trunk flexion, pounding, and shoulder movement and rotation. At one of the sites, where a force meter was placed at the end of a rock bar wedged under a large rock, the pull force to move the rock was measured to be 126 lbs. This amount of force resulted in over 600 foot-lbs of torque at the tip of the pry bar. For purposes of comparison, the recommended maximum pull force for males is about 72 lbs.[6]

Kitchen Patrol. The primary physical activities and stressful postures of KP duty were lifting and carrying water buckets weighing 35 lbs from the faucet to the fire; kneeling, squatting, and bending over to reach into plastic coolers containing perishable foods; lifting pots of food and coffee pots; lifting and carrying boxes and duffel bags while unloading supply mules; physical effort and shoulder movements and rotations to chop wood; and working at the various tables found at the camp site. Water also had to be carried from the fire to the wash table, but this was done individually with ordinary small cooking pans and ladles weighing just a few pounds. The height of the table at which food was served was 37 inches; the food preparation table inside the main tent was 36.5 inches high; the griddle was set at 38 inches, and the washstand table was at 40 inches.

Employee Interviews

Table III shows the results of the interviews for the 19 NPS and CCC workers organized by the main topics outlined in the Methods Section. Numbers in parentheses refer to the number of workers offering the same comment.

There were 14 males and five females on the trail crew. The average age of a crew member was less than 23 years, with the oldest being 33 years old. Only five of the workers were NPS employees, three of whom were among the four supervisors at the camp site. All of the workers considered themselves to be in average or good shape before starting work at Yosemite, and only four had any kind of injury or physical limitation before joining the back country trail maintenance crew. Fourteen of the workers considered moving rock to be the most difficult aspect of rock work, followed by drilling holes into rock with the gas-powered Pionjar™ tool.

All trail crew members were generally satisfied with their jobs and the conditions under which they performed them, but only three individuals had no suggestions for change. Sixteen workers thought that more and better safety equipment should be made available to workers, even though each article would not necessarily be used/worn on every job. The most common suggestions included providing knee pads, shin guards, and better face and foot protection for use when moving and breaking rock. Thirteen workers felt that alternative equipment for shaping and moving rock should be made available, even though it could not be used on every project.

Eleven of the 19 workers reported some type of musculoskeletal pain at the time of the survey, none of which prevented them from doing their jobs. Three of the five workers reporting back pain experienced sciatica, which is radiation of pain into the thigh and leg. Two workers reported nighttime awakening due to wrist discomfort, pain, and/or parasthesia. Moving rock was specified as the activity being performed in eight of the instances when the workers first felt any pain. Three workers felt that they needed more experience to perform their jobs better, and seven felt that there needed to be more emphasis on proper tool use and adherence to safety procedures.

Medical

Table I summarizes the injuries at Yosemite National Park for the years 1995–1997.

For each year, the numbers indicate new injuries, although repeat injuries during the year or multiple injuries affecting different parts of the body for an individual employee may be included. Over the three-year period, overexertion injuries accounted for 38.7 percent (234/604) of total Park injuries and 75.9 percent of total injuries (66/87) for NPS trail workers. Overexertion injuries for all Park employees declined from 1995 to 1996 (51 percent [(87/180)] vs. 34 percent [60/176]), but increased over the same period for the NPS trail employees (65 percent [17/26] vs. 86 percent [30/35]). Conversely, overexertion injuries for the total Park employees increased from 1996 to 1997 by 45 percent and decreased for NPS trail workers by 37 percent. The ratio of overexertion injuries to NPS trail employees for the three-year period was 38.6 percent (17/44) in 1995, 55.5

TABLE III
Results of interviews

Discussion item	Response
Gender	14 male, 5 female
Age	avg. = 22.7 yrs., range = 19–33 yrs.
Occupational history (NPS or CCC and how many years of each)	5 NPS-avg. trail work = 5.9 yrs. Range = 3–10 yrs. 14 CCC-avg. trail work = 1.75 yrs, range 1–6.5 yrs., 9 first-year workers.
Physical shape prior to working at Yosemite	good shape (14) average shape (5)
Any history of musculoskeletal problems before joining trail crew	**knee surgery** from soccer (1) **wrist problem** due to fall from motorcycle (1) **uneven shoulder** alignment (heredity) (1) **unspecified knee** injury (1) **no prior injuries** (15)
Description of the trail maintenance tasks worker had performed	**rock work** (rolling, shaping, use of pry bars, hammers, and Pionjar), **maintenance work** (raking, shoveling, brushing, lopping, use of saw pole, hand saw, chainsaw) (19)
Rating of which tasks were the most difficult and why	**moving rock** (14) "hard on the back," "have to move rock a long way," "moving the rock often the first thing done in the morning," "takes a lot of time," "rocks are heavy" **hiking to work site** (1) "a lot to carry to work" **shaping rock** (1) "hammer twists in my hand" **operating Pionjar** (2) "drill must be held straight," "requires a lot of experience to use" **unloading mules and hauling groceries** (1)
What aspects of the job could be changed or improved: organization or work, training, tools used, safety equipment, etc.?	**can't think of anything now** (3) **would like to see more protective equipment** (16) (knee pads, full face shields, safety glasses for prescription lens wearers, metatarsal guards, shin guards, back belts, better, more comfortable shoes, rubber sleeves on shaft of hammers and sledges to reduce shock, hard hats that are easier to adjust) **need a lightweight power tool to shape rock** (3) **would like to have grip hoists** and "come along" available for some jobs (3) **would like a wheel barrow** or jack to roll or slide rock (2) **need a better backpack** (internal frame) (1) **need more training** and specific directions at the start of the workday (3) **need longer and better handles** on small hammers to enable two-hand use (3) **would like need to bend over** and stoop eliminated (1) **camp should have** more than one Pulaski (2)
Any aches, pains, injuries now? Part of the body affected?	**tight back** due to rock work (5) **wrists hurt** due to rock work (2) **quadriceps muscle** hurts (1) **pulled leg** muscle (1) **wrists hurt** from KP (2)
Work task being performed when it happened	**moving** rock (8) **using sledge** hammer (1) **lifting pots**, chopping vegetables and kneading bread (2)
Does it affect your work now?	**no**-just work with the pain (11)
Other comments	**supervising the work** of others breaks up continuity, increases chances of getting hurt (2) **rock work harder** than trail grooming (5) **letting loose** of hammer just before impact reduces shock **must emphasize** proper lifting techniques (2) **I need more** experience (3) **I need to use** my rock bar more (2) **I'm going to try to remember** the safety training I got this year so that I don't get hurt next year like so many others (3) **everything we** need is supplied to us (1) **rock bar often** slips and pops out of rock (2) **would like a comfortable** place to sit at the camp site after work (5)

percent (30/54) in 1996, and 23.4 percent (19/81) in 1997. The total number of trail workers and NPS trail workers increased in 1997 from 1996 by 51.2 percent and 50 percent, respectively.

Among the trail workers, back injuries accounted for 41 percent (7/17) of the overexertion injuries in 1995, 37 percent (11/30) in 1996, and 31.5 percent (6/19) in 1997. In 1997, injuries to the knee occurred more frequently than back injuries, 36.8 percent (7/19). During the three-year period, two cases of carpal tunnel syndrome were reported by NPS trail workers.

At the Buena Vista camp, 3 of the 19 workers sustained a recordable or lost-time injury in 1997. Two of the injuries were to the back and one was a pulled leg muscle. The three injured workers were NPS supervisors. None of the 14 CCC workers had sustained an injury resulting in lost time during the 1997 trail maintenance season.

Discussion

Ergonomics

The trail construction and maintenance work that takes place in the back country of Yosemite National Park is performed largely with simple, primitive hand tools. The Pionjar™ for drilling into rock is an exception, but the tools and tool selection are maintained at a minimum level due to the environment in which the work is performed and the difficulty in getting and adapting power and mechanical tools to the job site. The lack of uniformity of the job tasks and the rocky, mountainous environment in which they take place would seem to preclude the widespread use of power and mechanical tools for reasons of time management. However, this view may not be as valid as it seems or as was expressed by the work crews because the video analysis indicated that about 25 percent of the time is spent adapting the available hand tools to the unique types of situations that are encountered when trying to move and shape rock at the trail sites. Workers also spend time repositioning themselves or the rock to get the best footing or the best leverage to move or strike the rocks. This time could conceivably be used to set up power equipment such as portable rock hammers, material handling equipment such as grip hoists and come alongs, and mechanical jacks that could reduce the physical effort of the workers performing the various rock work tasks.

Moving, shaping, and positioning rock with hand tools can never be devoid of repetitive movements and application of high muscular force in awkward postures, but recent trends in the appearance and quality standards of hiking trails may be increasing the exposure to cumulative trauma by the trail workers. Traditionally, front country trails were built and maintained to a high standard for purposes of longevity due to the volume of tourists who used them. Back country trails were rougher and more crude to coincide with the lower numbers of high-elevation, long-distance, and outdoor-camping hikers. However, front country standards for trail quality are now being applied in the back country as a means of reducing the amount of future reconstruction and maintenance. The idea is that once a trail is serviced, it may not need to be attended to again for many years. However, it does result in the trail workers increasingly performing the types of activities that are most likely to result in an injury. Whereas before, an acceptable step may have been a large rock that was shaped with a few blows from a large sledge hammer, the current trend in the back country is to build steps with carefully selected rocks that are moved greater distances and shaped not only with large sledge hammers, but with small hammers to the extent that they fit into place with little or no rock fill or mortar. This change in standards for back country trails may best be accompanied by a change in the tools and methods used to build them.

In general, the hand tools used were adequate for the job tasks on the trails, but observations and remarks from the workers suggest that some improvements in design would be beneficial. Based on worker comments, the rock bars could be more effective if they were equipped with rubber handles and wider blades. These enhancements would allow more hand force to be generated and prevent the tip from slipping off the rock. The handles would also serve to cushion any blows to the head or body if the bar happened to slip out of the worker's hand. Handles would also improve the use of the hammers. Several comments were made regarding the hammer slipping or twisting in the hand at impact and the handles of small hammers being too short for two-hand use. Better and longer grips on the hammers would reduce the amount of hand force needed to use the tools, which would reduce the risk of hand/arm injury. The improved ability to grip the tool may also allow the workers to select the heaviest hammer suited to breaking the rock, which is a measure that reduces the number of strikes required to complete a given task. The workers are trained in this manner, but until they become conditioned by the job, some inexperienced workers choose a smaller hammer and strike the rock more often to get the job done. According to the experienced NPS workers, the inability to use the right tool for a job due to inadequate strength is a major cause of injury, particularly early in the season.

Many of the worker comments pertained to increased availability of safety equipment and tools. Items suggested by the workers such as full face shields, shin guards, and metatarsal guards would reduce the likelihood of a worker getting hurt from airborne rock chips, for example, which might enable the workers to better position themselves for the most efficient application of force. In instances where the worker would be inclined to kneel, but chooses to squat to eliminate the pain of direct contact with crushed rock, knee pads would reduce biomechanical forces to the kneecap. The muscle and ligament forces imparted to the kneecap when one is in full squat are equal to eight times the body weight above the knee.[7] If workers had knee pads they could kneel instead of squat and reduce the force to the kneecap to just the body weight alone.

Thirteen workers commented on the need for more training in technique and safety practices or more experience performing rock work and properly using the tools. These comments were made at a time when there were three weeks remaining in the 1997 season. It may be that the practice of on-the-job training for new employees who are not "hardened" to physical work in a rough environment is no longer the best concept. The consensus was that the front country trail maintenance and repair work early in the season is easier than the back country construction work, and physically prepares the workers for the harder work that follows. Nonetheless, an organized program of work technique and physical conditioning training for trail maintenance and construction workers before they ever go into the field may be needed to ensure that workers are prepared to work safely and efficiently for the entire maintenance and construction season. A consideration would be to formalize the program by offering a certification in trail maintenance and construction. Work hardening and identification of light-duty tasks for injured workers are key elements in programs designed to reduce injuries and disabilities in physically intensive work tasks.[8] A formal training program, as described above, coupled with the efforts of the liaison position recently created at Yosemite, in which one of the emphasis areas is the identification of light-duty work for injured trail workers, would serve to form the basis for a proactive program for controlling work-related musculoskeletal disorders.

A practice already in place that is recognized as part of a sound program in controlling musculoskeletal disorders is the warm-up exercises that the workers perform at the camp site. The content of the observed warm-up exercises was beneficial, and doing them should be emphasized. Hiking to the job site each morning also provides a good warm-up, but workers should still endeavor to ease into the job by performing light activities such as arranging tools or finishing up the previous day's work before engaging in physically demanding tasks, such as moving a large rock. The worker who indicated hiking to be one of the most difficult jobs performed by the trail crews was mainly referring to hiking back to the camp site after a full day's work.

The camp sites in the back country are torn down and rebuilt each season, but the layout should incorporate ergonomic design principles, particularly regarding preferred heights for tables and placement of items in the camp site that are used often and by everyone. Many of the table heights were outside the comfortable range for most people, and the distances between the water spigot and the campfire, and the campfire to the wash table were excessive considering the weight of the water carried between them. Kitchen and camp site design and layout are addressed in the Recommendations section.

Back pain and injuries accounted for most of the disability at the Buena Vista Lakes camp and were the greatest concern expressed by the requesters of the HHE. There is no easy solution for these problem if the unassisted lifting and moving of heavy rocks continues to be a primary activity of the trail workers. The rock bar is probably the best type of tool for moving rock in the mountainous environment to avoid uncontrolled rolling of rocks. Widespread use of the rock bar minimizes the risk of injury, but the effective use of this tool requires considerable applied force. A rock bar design that generates more leverage without loss of control would be desirable. One positive aspect of the trail work is that the rocks are typically so heavy that rarely does anyone ever attempt to move one (either by hand or with a rock bar) without the aid of one or more workers. Nonetheless, the recommended weight limit for a lift made under ideal conditions defined in the NIOSH lifting guide is 51 lbs.[9] For comparison purposes, three workers attempting to roll a 600-lb rock by hand would each be lifting about twice as much as the NIOSH guide would recommend, under less than ideal conditions—bulky load, poor hand-to-load coupling, and poor footing, for example.

Medical

The increase in absolute number and percentage of overexertion injuries among trail workers in 1996 versus 1995 was the main reason the HHE request was made to NIOSH. Information regarding actual hours worked by employees, or measures of worker output over the three-year period, was not collected during the site visit. However, it is reasonable to believe that increasing the workforce by 50 percent in 1997, and thereby decreasing individual workloads, accounted for some of the decrease in total injuries and overexertion injuries sustained by NPS trail workers, compared to the previous year.

It is noteworthy that the three injuries at the Buena Vista camp in 1997 were sustained by NPS supervisors and none involved CCC workers. The NPS workers are older than those in the AmeriCorps program, and because the NPS workers teach and lead the CCC workers, they may have a higher physical stress exposure. The supervisors work on specific projects, but they also hike from site to site reviewing the progress of the less experienced workers and offering assistance where needed. This often results in the supervisors "jumping in" and taking the lead in a difficult maneuver such as dislodging a stuck rock. The added hiking may also predispose the supervisors to injury by adding to accumulated fatigue. The ratio of NPS to CCC workers (nearly one to four at Buena Vista) may be insufficient for the NPS workers to obtain adequate rest and recovery.

Conclusions

Ergonomics

- Many of the trail work tasks are physically intensive, performed with basic, unrefined tools.
- The most arduous tasks, namely moving and shaping rock, constitute more than 50 percent of the activities performed.
- The low ratio of experienced to inexperienced workers likely

has a detrimental effect on the injury patterns of the workers.
- Some degree of mechanization is needed to reduce the physical effort required by workers to perform their work.
- More safety equipment and training being made available to workers could reduce the risk of injury.
- Improvements in the design and layout of the kitchen and camp site could improve the musculoskeletal health status of all workers, not just the cook.

Medical
- Overexertion injuries, mostly to the back, are a large percentage of the injuries sustained by trail workers.
- Total injuries and overexertion injuries decreased in 1997 for trail workers compared to the previous year, but this cannot be explained by information collected during this evaluation. An increase in the number of trail workers from 1996 to 1997, resulting in decreased individual workloads, is a possible explanation.

Recommendations

The following recommendations were offered as a means of reducing the muscular and postural load sustained by the worker while performing the various rock work tasks in trail maintenance and construction.

Trail Work

Continue efforts to implement a written safety program containing the main elements of managed ergonomics programs. The elements are: (a) Worksite Analysis, (b) Hazard Prevention and Control, (c) Medical Management, and (d) Training and Education. These elements are discussed in the Occupational Safety and Health Administration (OSHA) Ergonomics Program Management Guidelines for Meatpacking Plants[8] and in the NIOSH Primer on Workplace Evaluations of Musculoskeletal Disorders.[10] The continuation of the newly formed liaison position would be a key factor in implementing the program because many of the provisions contained in the main elements are duties of this position, for example, analysis of medical records, identifying and defining light-duty tasks, and evaluating job hazards. Continuation of the good practices already in place is consistent with the implementation of an effective ergonomics/safety program. Examples are the warm-up exercises before work, emphasis on good safety and health practices such as use of proper lifting techniques (including two and three persons lifting), and use of existing personal protective equipment.

Provide better handles on hammers, sledge hammers, rock bars, and other hand tools to allow for better force application, better control, more comfort, and shock cushioning. In general, tool handles should be elliptical (egg-shaped), about 1.5 inches in diameter, and made of rubber or soft plastic. The small hammers should be modified to allow for two-handed use, and workers should be trained to hammer with both hands and ease their grip force at impact to reduce shock to the hand. The handle length should be increased 4 to 6 inches to comfortably allow for two-hand use.

Consider custom modifications of existing tools used to move rock, particularly the rock bar. A possibility would be an additional design added to the current types of rock bars available to the crews, having a wider tip for firmer and better-controlled contact with rock. A rock bar with a wider tip and a cushioned grip would also reduce the risk of traumatic injury in instances where the bar slips off the rock or out of the hands and the handle makes contact with the worker. A rock bar with a T-handle or T-handle attachment would allow two workers to apply force with the same tool, which might improve safety and control.

Consider adapting front-country mechanical devices to back-country work activities. These tools have in the past been dismissed as unusable in the back country, but some of this equipment could be used in certain applications if it were available. Examples of tools are grip hoists, come alongs, portable jacks, and wheel barrows. There are gas-powered rock drill/breaker tools weighing as little as 31 pounds that could be used to split and shape some rocks.

Arrange for the availability of more and improved safety equipment for workers. This type of equipment would protect the workers from traumatic injury, allow workers to position themselves for improved force application capability, and reduce internal and contact forces to joints that are associated with awkward postures. Items to be considered in an expanded safety equipment inventory include: full face masks for drilling and sawing tasks, metatarsal and shin guards for protection while hammering and drilling, knee pads, better-fitting safety glasses (particularly for prescription lens wearers), more comfortable and durable shoes, and more easily adjusted hard hats. Selection criteria for additional safety equipment should consider designs that facilitate widespread use. For example, knee pads that are sewn into the knees of work overalls, or hard hats that feature built-in face shields and hearing protection, are designs that should be given more serious consideration.

Consider more extensive conditioning and technique training for new workers. This recommendation is an elaboration of one of the main elements of the ergonomics program mentioned previously. Many workers who expressed the inability to handle heavy tools early in the season, or who said that early-season work physically prepared them for the more difficult end-of-season construction activities, would benefit from pre-season conditioning. Likewise, inexperienced workers would benefit from technique training from experienced workers. Examples are using two hands with small hammers, loosening one's grip just before impacting a rock,

selecting the smallest rock possible for a certain application, and splitting a rock (if it is deemed necessary) before it is ever rolled. These are subtle advantageous practices which many new workers do not learn until after an injury. Such injury prevention training is more important when one considers that crew members are new nearly every year, and the ratio of experienced/inexperienced workers tends to be low.

Kitchen and Camp Site

The kitchen and camp site, used by all trail crew members, should be designed and equipped in accordance with ergonomic principles. Tables and stove heights in the kitchen where forceful activities such as lifting pots or kneading dough take place should be no higher than 33 inches; tables where food is served or where workers wash their hands and dishes should be 35–37 inches high. Cooking utensils should be lightweight and, if hung overhead for storage, be within easy reach of everyone. The functional overhead reach for an average 50-50 mixed male/female population is 80.5 inches. Coolers used to store perishables should be oriented to minimize bending over to access them. The knee wall of the tents in use at Buena Vista could have accommodated coolers that were raised 13 inches above ground level. The normal practice of sinking the coolers into the ground, not done at Buena Vista due to rocky soil, would result in more kneeling, but less bending over, than was observed.

Key camp site fixtures that are carried to and from often should be as close to each other as possible, particularly when heavy loads are carried. The distance between the water source and the fire, and between the fire and the washing area, should be as short as possible.

Other recommendations for the Buena Vista Camp site:

- Assign one or two trail crew members to carry a large vessel of hot water to the washstand before meals to eliminate the need for everyone to walk back and forth between the fire and the table with small ladles of water.
- Consider installing a sink in the wash table that flows directly into the drain pit to eliminate the need for workers to wash with shallow pans and dump the water into the pit. The sink could also be used to wash dishes.
- Provide comfortable chairs for relaxing after the workday and to use while eating meals. Added comfort would likely serve to alleviate the back pain reported by some of the workers.
- Adjust the latrine height to allow most workers to rest their feet on the ground while using it. The seated lower leg height (popliteal height) for the average 50-50 mix of males and females is 16.6 inches.

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EDITORIAL NOTE: Daniel Habes is with the Hazard Evaluation and Technical Assistance Branch of NIOSH and Mark Schiefer, M.D., is an Occupational Medicine Resident at the University of Utah. More detailed information on this evaluation is contained in Health Hazard Evaluation Report No. 97-0199-2680, available through NIOSH, Hazard Evaluation and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226; telephone: (800) 35-NIOSH; fax: (513) 533-8513.