



IC 9504

INFORMATION CIRCULAR/2008

Keeping Knees Healthy in Restricted Work Spaces:

Applications in Low-Seam Mining



Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

NIOSH

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May 2008

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DHHS (NIOSH) Publication No. 2008-130

May 2008

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ACKNOWLEDGMENTS

The technical contribution of Diana Schwerha, Ph.D., and William J. Wiehagen is gratefully acknowledged, as well as the artistic works of Alexis Wickwire, Jonisha P. Pollard, E. William Rossi, Jacqueline M. Post, and William L. Porter.

KEEPING KNEES HEALTHY IN RESTRICTED WORK SPACES: APPLICATIONS IN LOW-SEAM MINING

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INTRODUCTION

Many challenges are faced by workers in lower-seam (42 inches or less) mines. The lower-seam heights confine mine workers to their knees as they perform their daily tasks such as installing roof bolts, delivering supplies, repairing belt, or cutting coal. Miners working in these lower seams often consider kneepads to be their only line of defense against knee injuries. However, healthy knees do not start and stop with kneepads. Other interventions such as changing postures, proper hygiene, and work station design may also be used to reduce mine workers' risks for developing knee injuries. Incorporating these and many other interventions into a mine worker's "way of life" is an important step to ensuring a long, healthy career and retirement. Keeping knees healthy is also a key aspect to reducing costs in low-seam mines as the industry battles rising health care costs, and training/recruitment of replacement workers is time-consuming and costly. Educating the workforce about the possible interventions to reduce knee injury risk is a primary objective for the National Institute for Occupational Safety and Health's (NIOSH) Pittsburgh Research Laboratory (PRL). Therefore, NIOSH researchers, along with industry and academia, developed a training package to educate the mining community about some possible interventions beyond kneepads that may be used to help decrease knee injury rates. Increased awareness and simple changes are the first steps to reducing knee injuries.

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TRAINING DEVELOPMENT

Knee injuries associated with working in low-seam mines have been a longstanding problem for the U.S. mining industry. Accident statistics from the Mine Safety and Health Administration (MSHA) indicate that over 50% of all knee musculoskeletal injuries occur in coal mining. Statistics also suggest that coal miners who incur a knee injury are away from work a median of 25 days, 10 days longer than those who are off for back injuries. It has also become difficult for mining companies to recruit and retain new miners, especially in low-seam conditions, because of the physical challenges of working on their knees.

Several attempts have been made to understand the effect of kneeling and crawling on knee health and to develop kneepads accordingly. These efforts have been unable to overcome the durability issue of kneepads in these harsh environments. In fact, during field evaluations of prototype designs, although mine workers seemed pleased with the new design, the kneepads came apart at the junction of the different materials. Advances in material science and manufacturing methods have occurred since these studies, and further NIOSH efforts in kneepad design are ongoing. However, previous studies did not measure the stresses applied to the knee when kneeling or crawling, which would be very beneficial during the design process. While this research is being conducted by NIOSH, additional interventions should be employed. Given the prevalence, costs, and interest from the mining industry, along with the increased knowledge about the development of knee injuries, this training package was developed to educate mine workers to reduce their exposure to injury risk factors.

Three mining companies with interest in knee injury reduction, along with the University of Pittsburgh's Physical Therapy and Bioengineering Departments, teamed up with NIOSH PRL researchers to determine the appropriate content and delivery of material to educate and introduce techniques to relieve and even prevent the long-term effects of physically working on one's knees. A preliminary program was developed by NIOSH and the University of Pittsburgh and presented to the three mining companies. A focus group approach was used to determine appropriate content and quantity of material, as well as to determine the tone of the messages. It was important to the mining companies that the mine workers understand how and why these injuries occur, the importance of their role in reducing injuries to their knees, and what practical changes they can make to keep their knees healthy on the job and at home other than relying on kneepads. Specifically, the mining companies wanted to provide workers with information regarding general knee anatomy along with common causes and symptoms of knee injuries. Finally, it was important that the training delivery be versatile (e.g., safety talks, annual refresher training, reminders), present a variety of practical solutions, and provide supplemental information so that trainers can gain a further understanding of knee anatomy and the injury process, if desired. Several iterations and pilot tests with these mining companies guided the training into its current format. The result was a modular training program with education of the injury process, workplace solutions, and simple exercises to strengthen and stretch the supportive knee structures. While mining companies are still interested in better kneepad design, the first step to reducing injuries is educating the workforce on the outcomes of habits, including kneepad hygiene and work methods. Research into the development of kneepad and workplace/equipment design is ongoing.

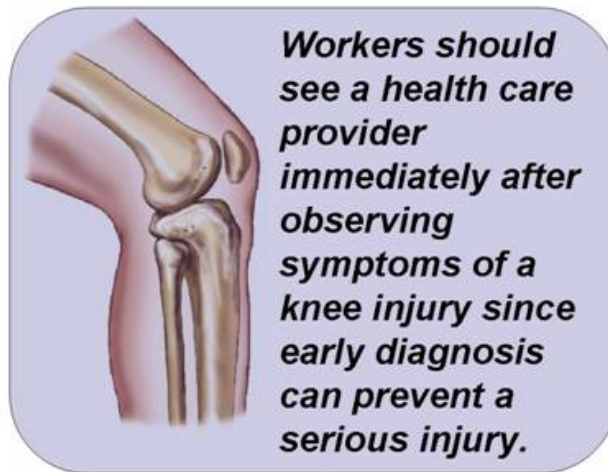
TRAINING PACKAGE

Three training modules were identified and developed: (1) Symptoms of Knee Injuries, (2) Protect Your Knees While at Work, and (3) Protect Your Knees for a Lifetime. Each module was designed with the mine workers as the target audience. Also, the modules were developed so that they may be introduced one at a time or all at once. This allowed mining companies to include one or more modules in annual refresher training. An Instructor's Guide was also developed to ensure the trainer was well-informed to deliver the training materials. This guide makes it possible for the training to be given by any mine safety and health representative or trainer. In addition to the training itself, it was also important to reinforce the principles and recommended practices throughout the year. Thus, a series of supplemental materials was developed that may be posted or handed out at various times.

Symptoms of Knee Injuries Module

The goal of this module is to introduce mine workers to basic knee anatomy and discuss symptoms and causes of knee injuries. Knee injuries common in low-seam mining are included in the training. Knee injuries are first broken down into two groups: overuse and traumatic. These injuries occur in two different ways, but both limit the mine worker's capabilities. Overuse (cumulative) injuries happen over time, whereas traumatic (acute) injuries happen instantly. Next, the symptoms and

possible causes of overuse injuries are discussed. Crawling and twisting on the knees for long periods of time are discussed as possible causes. The overuse injuries included in the materials are kneecap injuries, bursitis ("beat knee" or "miner's knee"), osteoarthritis, ligament tears, and meniscal tears. For each, pictures of the injured knee structures are provided. This gives the mine workers basic knowledge of how the knee works and the distinction between these types of injuries. To assist the instructor with this module, the Instructor's Guide includes more detailed information about knee anatomy. After discussing overuse injuries, the instructor summarizes the symptoms for each. The take-home message that mine workers should see a health care provider right after experiencing symptoms is highlighted again. It is important for mine workers to understand that early diagnosis can prevent a serious knee injury. Next, this same approach is taken for traumatic injuries. Pictures of knee anatomy and causes and symptoms of traumatic injuries are discussed. At the conclusion, the symptoms are summarized and seeing a health care provider early is promoted again.



Supplemental materials for this module include a poster, bulletins, and a safety talk. The poster's heading is "Aching Pain or Something More Serious?" (Figure 1) and carries the message that early diagnosis can lead to prevention. There are two smaller bulletins with the same theme that can be placed where the mine workers gather together (e.g., wash-room, elevator, and change-out room). This module also includes one safety talk. The goal of this safety talk is to remind mine workers of the common symptoms and causes of knee injuries. Again, the take-home message is that early diagnosis is important. The safety talk is designed to be given by the section foreman or direct supervisor before the start of a shift. These safety talks can be used as toolbox talks. They should take only 10 minutes and provide a chance to interact with other mine workers. This interaction is important since it helps encourage peer-to-peer conversations. Each injury covered in the training is also included in the safety talk. This reminds mine workers of the symptoms and that they should see a health care provider or company physician/nurse before they worsen. Additionally, the safety talk may be taken home by the mine workers to be used for future reference.

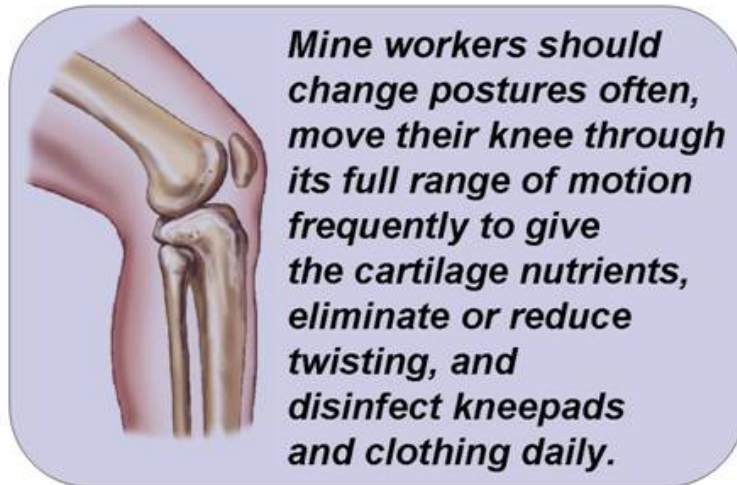


Figure 1. This is an example of a poster reinforcing the take-home message for the *Symptoms of Knee Injuries* module.

Protect Your Knees While at Work Module

The first goal of this module is to show on-the-job habits or activities that may increase the risk of getting a knee injury. To reduce the risk of knee injuries, several basic changes to how tasks are performed are then suggested. For example, the concept that different postures (e.g., kneeling, squatting) load different parts of the knee is explained. Thus, chang-

ing between postures better distributes forces and stresses. Mine workers then see the benefits of changing postures often. Remaining in the same posture for long periods of time has other effects as well. For example, it limits the nutrition to the cartilage, causing damage. Twisting on the knees is also a major concern. For this reason, several videos are used to show how mine workers can change their work area to eliminate or reduce twisting. Finally, poor hygiene is discussed since bacteria in kneepads and clothing may lead to bursitis or irritation of the skin. This is possible since bacteria can enter the knee through infected hair follicles, cuts, or abrasions. It is suggested that mine workers disinfect their kneepads and clothing daily. They may also switch between multiple pairs of kneepads to allow enough drying time between uses. At the end of this module, mine workers are encouraged to discuss problems at their mine site. They are also encouraged to brainstorm for ideas to address these problems. The take-home message for this module is that mine workers should change postures often, move their knee through its full range of motion frequently to give the cartilage nutrients, eliminate or reduce twisting, and disinfect kneepads and clothing daily.



This module contains the greatest amount of supplemental materials. The first is a poster entitled “Take Action to Protect Your Knees.” This poster reinforces all the take-home messages from this module. Four bulletins were also generated to further highlight the recommendations in this module. Two of the take-home messages covered by the bulletins refer to activities that the mine workers should incorporate during their shifts. Thus, these two bulletins were also made into reflective stickers. These stickers could then act as a reminder on a regular basis. Again, many of these items (Figure 2) encourage peer-to-peer conversations about the issues introduced in the module. The last item is a safety talk. This talk is to be covered by the section foreman or direct supervisor preshift. Each principle or practice suggested in the training is highlighted in this talk.

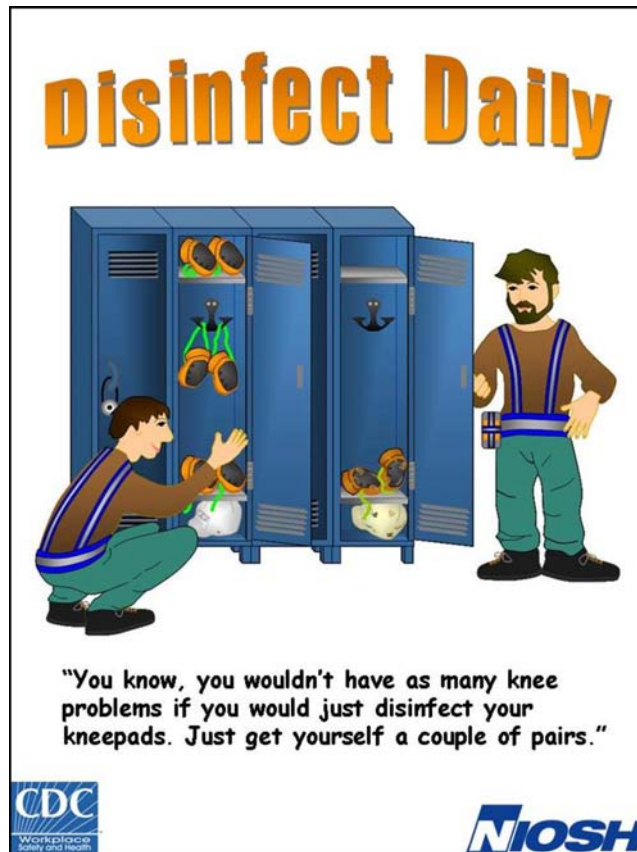
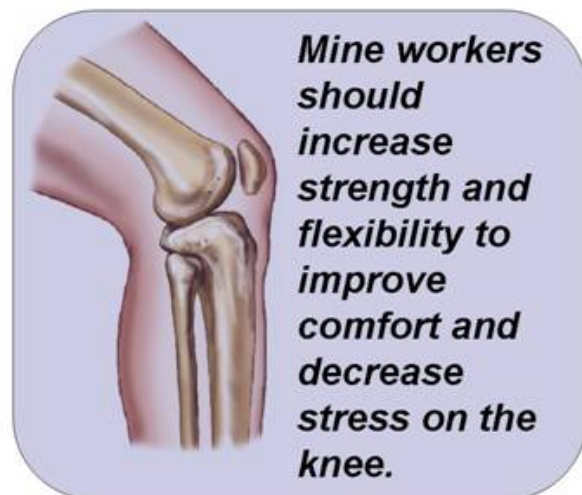


Figure 2. This is a sample bulletin reminding mine workers to disinfect their kneepads and clothing daily.

Protect Your Knees for a Lifetime Module

The goal of this module is to discuss the positive impact of increasing flexibility and strength at the knee on overall comfort and to reduce the risk of developing a knee injury. Increasing flexibility will improve joint motion and decrease joint stiffness. Less stress will be experienced by the knees. In this module, stretches for the muscle groups that are the primary movers of the knee are discussed. Each stretch was specifically selected by a physical therapist to ensure that minimal stress is placed on the low back while performed. It is important that stretches be performed in a safe and effective manner.



Therefore, demonstration videos are shown while a voice-over from a physical therapist describes in detail how to perform each stretch. The frequency and duration that mine workers should perform these stretches are also provided. The benefits of increasing strength, e.g., absorbing shock and protecting ligaments and cartilage, are presented. Demonstration videos with voice-over are included to ensure that the exercises are done safely and effectively. All of these stretches and strengthening exercises may be done in the home without the use of equipment. However, some individuals may wish to incorporate more rigorous exercises or add to their current gym workout. For those mine workers, a series of gym exercises is also introduced and demonstrated. Finally, mine workers are given information to determine if they are “overdoing it.” This is important to emphasize to avoid causing an injury. The take-home message for this module is that mine workers should increase strength and flexibility to better condition the knee and its supportive muscles, which will improve overall knee comfort and decrease stresses on the knee.

Supplemental training for this module includes two safety talks and one flyer. These safety talks remind mine workers of how to perform the stretches and exercises to increase flexibility and strength. The talks can be discussed preshift by the section foreman or direct supervisor. This allows the importance of these at-home activities to be reinforced in the workplace. Similarly, the bifold flyer depicts these same stretches and exercises. It is suggested that the flyer be given to the mine workers the same day as the training. This will allow them to take the information home and begin a stretching and strengthening program right away.

Instructor’s Guide

The Instructor’s Guide identifies the objective of the training and the benefits for both the mine and the mine worker. It also encourages the use of a “champion” to oversee the entire training process. The champion must also respond to any concerns or suggestions reported by the mine workers. The Instructor’s Guide also recommends that the trainer revise the materials when possible to reflect the particular worksite where the training is being given (e.g., pictures of mine workers doing various job tasks).

For each module, detailed information and a recommended script are provided for each slide. Additionally, a description of the supplemental materials provided for each module is included, along with the recommended use of each. Due to the large number of supplemental materials, a suggested plan for when and how to distribute these materials plan is also provided.

Finally, methods for evaluating the success of the training are discussed. An evaluation form is provided to obtain baseline knee discomfort data. Establishing a baseline is important since it allows progression of injuries to be tracked. Additionally, it allows for a before-and-after comparison following the implementation of changes in employee practices or work area design. These are all key parameters when evaluating the success or impact of this training and other interventions. Other methods for evaluating the success of the training include noting the number of changes discussed and requested.

Also, the number of mine workers using the suggestions from the training may be used to indicate whether the mine workers perceived the training as useful. Determining the number of mine workers who have begun using the stretching and strengthening program at home may also be a good measurement. The Instructor's Guide concludes by suggesting that anyone interested in this training package monitor the NIOSH Mining Web site (<http://www.cdc.gov/niosh/mining>) from time to time to see if any new research or information has been added to the training.

NEXT STEPS TO HEALTHY KNEES

This training package is only a first step toward reducing the risk of knee injuries in low-seam mining. Future research should consider the design and implementation of various interventions that may further reduce this risk. One area where research is needed is in the design of personal protective equipment such as kneepads that help reduce forces and stresses at the knee. At this time, there is a lack of information about the forces and stresses at the knee during mining tasks. Research in fabrication, materials, and design would also be beneficial since durability, moisture, comfort, and resistance to bacteria are a concern.

Research in the area of equipment design to reduce knee musculoskeletal disorders is also needed. Redesign of equipment should focus on reducing twisting at the knee or decreased time spent on one's knees. Determining the usefulness of other interventions such as work method changes and job rotation strategies may also be beneficial to the mining industry.

APPENDIX

Preliminary Interviews With Mine Workers

Before developing the training package, interviews were conducted with mine workers to collect information related to knee pain, exposures from work that can cause knee pain, and methods used by the miners to reduce their potential for knee pain and injury. A total of 23 mine workers were interviewed within an age range of 21–61 years (mean \pm standard deviation (SD): 40 ± 13 years). The experience level of the mine workers ranged from 1 month to 35 years, with mean and SD of 12 ± 13 years.

Ninety-five percent of the mine workers indicated that they experience knee pain as a result of their work in low seams. Roof bolting, shoveling (scoop operator), belt moves, and any tasks requiring extended crawling (e.g., section foreman) or staying in one posture in wet conditions (e.g., maintenance tasks) were all highlighted as tasks leading to knee pain.

The participants also offered ways to protect their knees from injury and reduce the potential for knee pain: (1) wear kneepads, (2) keep rocks from beneath the kneepad, (3) glue padding from a second pair of kneepads into their existing kneepads, (4) stretch muscles, and (5) keep their kneepads and clothing dry.

Implementing Feedback From Pilot Testing

The pilot version of this training package was given to mine workers at four different sites. In each case, it was part of their annual refresher training. The pilot version included the same three modules as in the final version. However, the only supplemental materials given out were the stretching and exercise flyer and the poster for the *Protect Your Knees While at Work* module. Feedback from the pilot testing was received through an evaluation form about the suggested activities in the *Protect Your Knees While at Work* module and the success of the training package overall. Also, discussions with the mine workers during and after the training were documented. With these data, the training package was revised to better address the issue of knee injuries in low-seam mining.

Evaluation forms for the pilot testing of the training package were obtained for 164 participants. The average age was 39.2 years, whereas the average years of job experience and low-seam experience were 10.8. Participants were asked, “Is it practical to minimize twisting while on your knees?” Ninety percent of the mine workers responded that they felt it was practical to minimize twisting on their knees as discussed in the training, whereas only 8% indicated that this was not a practical suggestion. While 90% of the mine workers felt minimizing twisting was practical, only 72% indicated that they would incorporate this concept into their daily tasks. Reasons for not incorporating this concept included: being “too busy,” “too many things to do,” “won’t think to do it,” and “on good production days time allotment for duties poses problems.”

Eighty-five percent of the participants felt that alternating between low and high kneeling postures was practical, with 75% stating that they would incorporate this into their daily tasks. Only 13% felt this suggestion was not practical. Again, being too busy and having many tasks to complete were listed as reasons for not incorporating this into their workday.

Ninety-one percent of participants felt that moving their knee through its full range of motion to lubricate the joint was a practical suggestion, with only 7% indicating that it was not practical. Similar to what was observed with the other suggestions, the number of mine workers that indicated they would adopt this new work habit decreased from the number that felt it was practical. However, a large percentage (77%) still indicated that they would incorporate this activity.

Based on these data, revisions were made to the pilot version of the training package.

- Additional supplemental materials were designed to remind the mine workers to incorporate the suggested practices from the training.
- Supplemental materials that may be taken home by the mine worker were also included so that they may act as a reference in the future (e.g., knee injury symptoms).
- The training modules were revised to indicate that the suggested methods would benefit mine workers that both have and do not have a current knee injury.
- The *Protect Your Knees While at Work* module was revised to emphasize that the redesigned work station videos demonstrate simplistic and realistic workplace changes and can be used as a basis for discussion and interaction with the audience.

Additional Activities that May Be Beneficial

In addition to the recommendations made within the context of the training package, there are other noninvasive treatments or therapies that address issues with pain, stretching, and exercise. While these are not currently endorsed by NIOSH, a brief discussion is provided to allow individuals the opportunity to consider discussing them with a health care provider. These include (1) applying trigger-point myotherapy or massage, (2) low-impact/stress exercise and stretching using a mini-trampoline or rebounder and/or a Swiss exercise ball (larger size, e.g., 24-inch diameter). Perlman et al. [2006] reported that general massage techniques (petrissage, effleurage, tapotement) to the knee area and surrounding muscles and soft tissue may help reduce pain in people with knee osteoarthritis. Similarly, trigger-point therapy is a method of identifying tightness in the leg muscles surrounding the knee that can refer pain or discomfort to the knee. Janet G. Travell, M.D.,⁷ is generally recognized as the leading pioneer in presenting the reality and importance of myofascial pain and its diagnosis and treatment [Davies and Davies 2007]. This technique is described by Davies and Davies [2007] and Prudden [1980,

⁷Dr. Travell served as the White House physician during the Kennedy and Johnson administrations. President Kennedy appointed her to this position as an expression of gratitude for her treatment of his debilitating myofascial pain and certain other ailments [Davies and Davies 2007].

1984]. Mine workers may wish to consider discussing this type of therapy with their health care provider. Briefly, this method involves locating the “trigger points” in a muscle and then applying acupressure (nominally for 10 seconds) with a thumb, fingers, elbow, or a tool (e.g., Backnobber, NolaRola, Thera Cane) specifically designed for the purpose. A spouse, family member, or other individual can assist if necessary. This method has been suggested as means for dealing with knee pain or discomfort and is not intended to replace the advice and recommendations of licensed professionals, such as a physical therapist, physician, or chiropractor.

Rebounding on a mini-trampoline or exercise ball is a low-impact exercise that may be beneficial for strengthening leg muscles. The rebounder can be used in a variety of ways. Merely standing on the rebounder may be beneficial as the muscles contract to maintain balance and stability. Research in this area is ongoing, and benefits have been debated. However, several proposed benefits of rebound exercise include the following [Carter 2005; Wellman 2003]:

- Provides aerobic exercise without incurring stress to the joints
- Provides “no impact” aerobics, especially helpful for those with a disability or who are arthritic, elderly, or have a compromised immune system with limited mobility
- Has a stabilizing effect on the nervous system, thereby reducing stress
- Increases endorphin output, thereby promoting the relaxation response
- Increases oxygen uptake and promotes detoxification via the lungs, skin, and lymphatic system
- Stimulates healing and cleansing [Brooks 2002]
- Has a natural analgesic effect on the body, relieving pain in the neck, back, and head by increasing circulation and oxygen flow [Walker 1989]

The use of an exercise ball (e.g., used in seated, reclining, kneeling positions) is another option to consider for low-impact exercise to simulate the motion of the rebounder. It may also be used to assist in stretching muscles. Use of an exercise ball is discussed by Creager [1994].

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DHHS (NIOSH) Publication No. 2008-130

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